Crosscutting Area:	***Human Health and Countermeasures (HHC)***				
Discipline:	***Bone Loss***				
Risk:	***(1) Accelerated Bone Loss and Fracture Risk***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
1a	What is the relative risk of sustaining a traumatic and/or stress fracture for a given decrement in bone mineral density, or alteration in bone geometry, in an astronaut-equivalent population who are physically active?	3	5	1	Risk Assessment
1b	Will a period of rapid bone loss in hypogravity be followed by a slower rate of loss approaching a basal bone mineral density (BMD)? What are the estimated site-specific fracture risks as one approaches basal BMD?	2	5	1	Risk Assessment
1c	Is there an additive or synergistic effect of gonadal hormone deficiency in men or women on bone loss during prolonged exposure to hypogravity?	1	5	5	Risk Assessment
1d	What biophysical modalities, nutritional modifications, and pharmacological agents (alone or in combination) will most effectively minimize the decrease in bone mass due to extended hypogravity exposure?	1	5	1	Countermeasures
1e	What are the specifics of the optimal exercise regimen with regard to mode, duration, intensity and frequency, to be followed during exposure to hypogravity so as to minimize decreases in bone mass? Is impact loading an essential element and, if so, how can it be produced in hypogravity?	1	3	1	Countermeasures
1f	What combination of exercise, biophysical modalities, nutritional modifications, and/or pharmacological agent(s) is most effective, efficient (minimal crew time), and safe, in preventing bone loss during exposure to hypogravity?	1	5	1	Countermeasures
1g	What are the important predictors for estimating site-specific bone loss and fracture risk during hypogravity exposure, including, but not limited to ethnicity, gender, genetics, age, baseline bone density and geometry, nutritional status, fitness level and prior microgravity exposure?	1	5	1	Risk Assessment
1h	Does the hypogravity environment change the nutritional requirements for optimal bone health?	3	3	2	Mechanisms
1i	What diagnostic tools can be utilized	2	5	1	Medical Diagnosis

	during multi-year missions to monitor and quantify changes in bone mass and bone strength?				& Treatment
1j	What systemic adaptations to hypogravity are important contributory factors to bone loss, evaluations of which are essential to effective countermeasure development (e.g., fluid shifts, altered blood flow, immune system adaptations)?	3	5	2	Countermeasures, Mechanisms
1k	Are hypogravity-induced changes in bone density, geometry, and architecture reversible upon encountering partial gravity exposure, or on return to full gravity (1-G)?	1	5	1	Risk Assessment
1l	What regimen (exercise, pharmacological, nutritional, or biomechanical including impact loading or artificial gravity exposure) will most effectively hasten restoration of bone mass and bone strength (geometry and architecture) to pre-flight values in returning crewmembers?	2	5	2	Countermeasures

Crosscutting Area:	***Human Health and Countermeasures (HHC)***				
Discipline:	***Bone Loss***				
Risk:	***(2) Impaired Fracture Healing***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
2a	Is the rate of fracture healing and the integrity of the healed fracture altered under hypogravity or unloaded conditions?	1	1	1	Risk Assessment
2b	Are there site-specific differences or differences in healing diaphyseal bone versus metaphyseal bone under microgravity or partial-gravity conditions?	3	3	3	Risk Assessment
2c	Which cellular and biochemical changes in bone cell biology alter fracture healing under microgravity conditions?	4	4	4	Mechanisms
2d	Does the presence of microgravity-induced alteration in bone remodeling and/or osteoporosis affect fracture callus remodeling?	2	2	2	Mechanisms
2e	How do changes in skeletal muscle-bone interactions during spaceflight contribute to altered fracture healing in microgravity?	4	4	4	Mechanisms
2f	Do biophysical modalities play a role in improving fracture healing in a microgravity environment?	2	2	2	Mechanisms
2g	Do biophysical modalities play a role in	2	2	2	Mechanisms

	improving fracture healing in the presence of bone loss in a microgravity environment?				
2h	Are there anabolic agents, growth factors, or cytokines that will speed fracture repair during microgravity in combination with active bone loss due to unloading?	1	1	1	Countermeasures
2i	What technologies will be used to diagnose fractures of the axial and appendicular skeleton in a space environment?	1	1	1	Medical Diagnosis & Treatment
2j	Will different technologies be needed to treat either open or closed fractures in a space environment?	1	1	1	Medical Diagnosis & Treatment

Crosscutting Area: ***Human Health and Countermeasures (HHC)***
Discipline: ***Bone Loss***
Risk: ***(3) Injury to Joints and Intervertebral Structures***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
3a	What is the cause of the back pain commonly experienced by crewmembers upon return to 1-G?	2	3	2	Mechanisms
3b	Is damage to joint structure, intervertebral discs, or ligaments incurred during or following hypogravity exposure?	2	3	1	Risk Assessment
3c	What countermeasures will protect joint and intervertebral soft tissues (e.g. discs and ligaments) from microgravity or partial gravity-related damage?	2	2	1	Countermeasures
3d	What rehabilitative measures will hasten recovery of soft tissue damage in a partial gravity environments, or upon return to Earth's gravity?	2	2	1	Medical Diagnosis & Treatment

Crosscutting Area: ***Human Health and Countermeasures (HHC)***
Discipline: ***Bone Loss***
Risk: ***(4) Renal Stone Formation***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
4a	What diagnostic measures permit detection of renal calcification during extended-duration spaceflight?	4	1	1	Medical Diagnosis & Treatment
4b	What nutritional and/or pharmacological countermeasures adequately minimize risk of stone formation in-flight and upon return to 1-G?	3	2	2	Countermeasures
4c	What is the time course of increased risk for renal stone formation abating upon return to 1-G?	3	3	2	Risk Assessment

Crosscutting Area:	*Human Health and Countermeasures (HHC)*				
Discipline:	*Cardiovascular Alterations*				
Risk:	*(5) Occurrence of Serious Cardiac Dysrhythmias*				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
5a	Does spaceflight increase susceptibility to serious cardiac dysrhythmias?	1	1	1	Risk Assessment
5b	What conditions of spaceflight (e.g., microgravity, disruption of physiological rhythms, nutrition, environmental factors and radiation) may be responsible for cardiac dysrhythmias, and what are the mechanisms involved?	1	1	1	Risk Assessment
5c	Can risk of serious cardiac dysrhythmias be predicted for individual crewmembers?	1	1	1	Risk Assessment
5d	What countermeasures may prevent or reduce the occurrence of serious cardiac dysrhythmias during long-term spaceflight?	1	1	1	Countermeasures
5e	Can susceptibility to, and occurrence of, serious cardiac dysrhythmias be effectively diagnosed and treated during spaceflight?	1	1	1	Risk Assessment
5f	Which cardiovascular diseases are likely to be aggravated by spaceflight, and what mechanisms are involved?	1	1	1	Risk Assessment
5g	What screening methods on the ground and in-flight might identify crewmembers with underlying cardiovascular disease, which may be aggravated by spaceflight?	1	1	1	Countermeasures

Crosscutting Area:	*Human Health and Countermeasures (HHC)*				
Discipline:	*Cardiovascular Alterations*				
Risk:	*(6) Diminished Cardiac and Vascular Function*				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
6a	Does long-duration spaceflight lead to diminished cardiac function? If so, what mechanisms are involved?	1	1	1	Risk Assessment
6b	Is spaceflight-induced diminished cardiac function reversible?	1	1	1	Risk Assessment
6c	What is the extent of reduction in cardiac function and/or mass associated with long-duration spaceflight?	1	1	1	Risk Assessment
6d	Can susceptibility to reduced cardiac function be predicted for individual crewmembers?	2	2	2	Risk Assessment
6e	What countermeasures may be effective	1	1	1	Countermeasures

	in mitigating the occurrence of reduced cardiac function or mass?				
6f	What are the physiological and environmental factors by which spaceflight decreases orthostatic tolerance?	1	1	1	Mechanisms
6g	How does duration of spaceflight affect the severity and time course of orthostatic intolerance, and what are the mechanisms?	2	2	2	Mechanisms, Risk Assessment
6h	Is orthostatic intolerance likely to develop on the surface of Mars or the moon?	1	1	1	Risk Assessment
6i	Can spaceflight-induced orthostatic intolerance be predicted for individual crewmembers?	1	1	1	Risk Assessment
6j	What countermeasures can be developed to overcome or prevent orthostatic intolerance?	1	1	1	Countermeasures
6k	What are the physiological and environmental factors by which spaceflight decreases aerobic exercise capacity?	1	1	1	Mechanisms
6l	Is the observed decrease in exercise capacity directly related to duration of spaceflight?	1	1	1	Mechanisms
6m	Can the degree of reduced aerobic exercise capacity be predicted for individual crewmembers?	1	1	1	Countermeasures, Risk Assessment
6n	What countermeasures can be developed to overcome microgravity-induced reduction in aerobic exercise capacity?	1	1	1	Countermeasures

Crosscutting Area:	***Human Health and Countermeasures (HHC)***
Discipline:	***Environmental Health***
Risk:	***(7) Define Acceptable Limits for Contaminants in Air and Water***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
7a	What are the most likely sources of severe air and water pollution specific to ISS, lunar, and Mars missions, and what methods can be used to control these sources over long periods of time?	1	1	1	Risk Assessment
7b	What are the tolerance limits in terms of quantity and type of microorganisms in air, water, and food, and on surfaces?	1	1	1	Risk Assessment
7c	What approaches to setting exposure standards may be used when insufficient data are available to allow prediction of acceptable exposure levels?	1	1	1	Risk Assessment
7d	What is the requirement for determining how rapidly acceptable air quality can be recovered after a severe pollution	1	1	1	Risk Assessment

	condition and what effect that recovery has on humidity condensate and the water recovery system?				
7e	Can automated real-time systems be used to monitor air and water quality for lunar and Mars missions, and can the crew interpret results without ground support?	1	1	1	Countermeasures
7f	How can traditional limited-time exposure and human toxicological data be used to predict acceptable values for inhalation exposures to single chemicals and/or mixtures?	2	2	2	Risk Assessment
7g	What impact do space flight-induced biological, physiological, and immunological changes have on the susceptibility of crewmembers to infectious agents and toxic substances in the air and water?	2	2	2	Risk Assessment
7h	What are the effects of exposure to ultra fine and larger (respirable and non-respirable) particles (e.g., lunar dust) on crew health, safety and performance?	3	2	2	Risk Assessment
7i	What are the interactions of microbes, chemicals and plants in CELSS on air quality?	3	2	2	Mechanisms
7j	To the extent that plants are critical to mission success, will the potential for phytotoxicity be adequately addressed in the evaluation of air quality?	3	3	2	Risk Assessment
7k	Is there potential for increased heterogeneity in terms of the distribution of air contaminants in the relatively larger lunar and Mars habitats? If so, what additional monitoring resources and/or strategies are necessary to protect crew health?	3	2	2	Countermeasures, Risk Assessment

Crosscutting Area:	***Human Health and Countermeasures (HHC)***				
Discipline:	***Immunology & Infection***				
Risk:	***(8) Immune Dysfunction, Allergies and Autoimmunity***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
8a	What are the molecular and genetic mechanisms that are affected by spaceflight-related environments (e.g., radiation, microgravity, stress, isolation, sleep deprivation, extreme environments, nutritional deficiency, and social interactions) that can result in the loss of immunoregulation/immune tolerance and/or affect innate/acquired immunity, respectively?	1	1	1	Mechanisms
8b	Can the effects on immune function	1	1	1	Risk Assessment

	(innate/acquired immunity), or dysfunction (loss of tolerance/immune surveillance), be summarized as a consequence of the conditions relating to each mission and/or its duration (i.e. 1-year ISS, 30-day lunar, 18-month Mars)?				
8c	What autoimmune diseases or allergies may affect astronauts exposed to spaceflight environments of different missions and/or durations?	1	1	1	Risk Assessment
8d	Are there detection systems that can identify the first alterations in immune regulatory networks (identify surrogate markers of immune function/dysfunction) so that therapeutic interventions can be instituted?	2	2	2	Countermeasures, Risk Assessment
8e	What steps can be taken during spaceflight to modify immune function as it relates to autoimmunity or atopic disease?	2	2	2	Countermeasures
8f	Will it be possible to use immuno-regulatory agents to prevent immune imbalances with respect to the development of atopic or autoimmune diseases?	1	1	1	Countermeasures
8g	Will nutritional supplements be able to modify immune responses by working in concert with other immuno-modulators to reduce atopic and/or autoimmune disease?	1	1	1	Countermeasures
8h	What pharmalogical agents used during long-term spaceflights, or interactions between pharmalogical agents, negatively affect the immune system?	1	1	1	Risk Assessment

Crosscutting Area:	***Human Health and Countermeasures (HHC)***
Discipline:	***Immunology & Infection***
Risk:	***(9) Interaction of Spaceflight Factors, Infections and Malignancy***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
9a	What types of latent infections (e.g., viral infections) will become reactivated as a function of spaceflight-associated factors and pose the greatest threat to human health as a function of compromised immunity resulting from space travel?	1	1	1	Risk Assessment
9b	What commensal organisms have the potential of establishing a primary infection and pose the greatest threat to human health as a function of compromised immunity resulting from space travel?	1	1	1	Risk Assessment

9c	What diagnostic, environmental monitoring, or laboratory technologies need to be developed for the identification of pathogenic microorganisms, and prevention or diagnosis of infectious diseases while in space (e.g., bacterial, viral, or fungal typing in real-time)?	1	1	1	Countermeasures
9d	Will the severity of disease(s) resulting from latent infection reactivation, and/or infections caused by commensal organisms (as a function of spaceflight-associated factors), be affected by the space mission and/or its duration (i.e. 1-year ISS, 30-day lunar, 30-month Mars)?	1	1	1	Risk Assessment
9e	Are there neoplastic malignancies that may result from latent infection reactivation, and/or infections caused by commensal organisms (as a function of spaceflight-associated factors), that will be affected by the space mission and/or its duration?	2	2	2	Risk Assessment
9f	Is it possible to predict the summary effects of each component condition and duration of spaceflight that results in an infectious and/or neoplastic state?	2	2	2	Risk Assessment
9g	Will it be possible to develop nutritional supplements to augment anti-microbial and/or anti-tumor therapies?	2	2	2	Countermeasures
9h	Will it be possible to restore immunity in a severely immunocompromised astronaut with autologous stem cell transplants?	3	3	3	Countermeasures
9i	What steps can be taken during spaceflight to boost immune function, and what antimicrobial therapies and immunological treatments can be used to prevent or cure infections?	2	2	2	Countermeasures
9j	Will it be possible to use anti-viral, -bacterial, or -fungal agents aboard spaceships to reduce pathogen burdens or to treat infections?	2	2	2	Countermeasures
9k	Will therapeutic agents aboard spacecraft function to reduce or treat tumor development?	3	3	3	Countermeasures

Crosscutting Area:	***Human Health and Countermeasures (HHC)***
Discipline:	***Immunology & Infection***
Risk:	***(10) Alterations in Microbes and Host Interactions***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
10a	What technologies will monitor, detect, quantify or identify microorganisms that	1	1	1	Medical Diagnosis & Treatment

	pose a threat to human health during a mission as a countermeasure for preventing further contamination or disease (e.g., bacterial, viral, or fungal typing in real-time)?				
10b	Does the spacecraft environment exert selective pressure on microorganisms that presents the crew with increased health risks (e.g., Helicobacter and ulcers)?	1	1	1	Mechanisms, Risk Assessment
10c	Does spaceflight alter microbial growth rates, mutation rates, or pathogenicity?	1	1	1	Mechanisms, Risk Assessment
10d	Does spaceflight alter the exchange of genetic material between microorganisms?	1	1	1	Mechanisms, Risk Assessment
10e	Does spaceflight alter host:microbe balance?	1	1	1	Mechanisms, Risk Assessment
10f	Do microorganisms associated with biological life support systems or biological waste treatment systems enter the general spacecraft environment with consequent increase in health risks?	3	1	1	Risk Assessment

Crosscutting Area:	***Human Health and Countermeasures (HHC)***				
Discipline:	***Skeletal Muscle Alterations***				
Risk:	***(11) Reduced Muscle Mass, Strength, and Endurance***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
	Global/Systemic				
11a	What combination of non-invasive modalities (exercise regimens, etc.), nutritional and micronutrient supplements, and hormonal or pharmacological interventions is most effective in protecting or increasing skeletal muscle mass, strength, and endurance prior to or during spaceflight?	1	1	1	Countermeasures
11b	What hardware and/or technology is/are reliable and effective in preserving muscle mass, strength, and endurance during an ISS mission?	3	3	3	Countermeasures
11c	Can any one or combination of non-invasive modalities (exercise regimens, artificial gravity, etc.) protect or build muscle mass or maintain muscle strength and endurance during an ISS, lunar, or Mars mission?	1	1	1	Countermeasures
11d	Can non-invasive countermeasures (resistive exercise, artificial gravity, etc.) aimed at counteracting atrophy processes during an ISS, lunar, or Mars mission maintain those deficits in skeletal muscle strength that appear to occur independently of the atrophy process?	1	1	1	Countermeasures

11e	What technologies (e.g., ultrasound) can be used to monitor and quantify changes in skeletal muscle size, strength, and endurance during spaceflight?	3	3	3	Countermeasures
11f	Does atrophy of the spinal musculature contribute to lower back pain in crewmembers during spaceflight or upon returning from an ISS, lunar, or Mars mission?	3	3	3	Countermeasures
11g	What are the effects of skeletal muscle atrophy on whole body metabolism (e.g., insulin and glucose tolerance) during spaceflight?	1	3	1	Countermeasures
11h	What are the effects of skeletal muscle atrophy on thermoregulation during spaceflight?	3	3	3	Risk Assessment
11i	What assistance devices/technologies can compensate for losses in skeletal muscle and endurance during spaceflight?	3	3	3	Mechanisms
11j	Is the skeletal muscle atrophy, loss in skeletal muscle strength, and reduction in skeletal muscle endurance that occurs during an ISS, lunar, or Mars mission completely reversible upon return to Earth?	1	3	1	Mechanisms
11k	What prescription modality(ies) (exercise regimens, physical therapy, etc.) facilitate recovery of skeletal muscle mass, strength, and endurance in crewmembers returning from an ISS, lunar, or Mars mission?	1	1	1	Mechanisms
	Nutrition				
11l	What are the nutritional and micronutrient requirements to maintain skeletal muscle mass during ISS, lunar, or Mars missions? (See also 18g and 18h)	3	3	3	Mechanisms
	Skeletal Muscle/Cellular				
11m	What cellular processes/signaling pathways in skeletal muscle can be identified and targeted (pharmacological, gene therapy, hormones, etc.) to prevent or attenuate fiber atrophy, loss of skeletal muscle strength, and reductions in skeletal muscle endurance during ISS, lunar, or Mars missions?	3	3	3	Mechanisms
11n	Is the capacity of skeletal muscle to grow or regenerate (satellite cells) compromised during or after a mission because of spaceflight conditions (e.g., radiation exposure, reduced skeletal muscle tension)?	3	2	1	Mechanisms
11o	Does skeletal muscle atrophy of the lower extremity musculature (i.e. muscle pump) affect cardiovascular function (e.g., orthostatic hypotension) during an ISS,	1	1	1	Countermeasures

	lunar, or Mars mission?				
	Bone/Tendon				
11p	Does site-specific skeletal muscle atrophy contribute to the accelerated rate of bone loss in the central and peripheral skeleton because of countermeasures targeting select muscle groups and/or reduced forces at the tendon insertion sites during spaceflight?	1	2	1	Countermeasures
11q	What are the temporal relationships between the changes in structure and function of the tendon, skeletal muscle and skeletal muscle-tendon interface during spaceflight?	2	2	1	Countermeasures
11r	How does the atrophy process affect the structural and functional properties of connective tissue (tendons), the fiber-tendon interface and the tendon-bone interface during spaceflight?	2	2	2	Risk Assessment
	Sensory-Motor				
11s	How do the deficits in skeletal muscle mass associated with spaceflight affect the structural/functional properties of the sensory system and motor nerves?	1	1	1	Risk Assessment
11t	To what extent do alterations in the sensory-motor system contribute to deficits in skeletal muscle strength and endurance during spaceflight?	3	3	3	Risk Assessment

Crosscutting Area:	***Human Health and Countermeasures (HHC)***				
Discipline:	***Skeletal Muscle Alterations***				
Risk:	***(12) Increased Susceptibility to Muscle Damage***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
12a	What prescription guidelines and compliance factors facilitate increased resistance to skeletal muscle and associated connective tissue injury in crewmembers prior to spaceflight?	3	3	3	Countermeasures
12b	What hardware and/or technology is/are effective in preserving muscle structure during an ISS mission?	3	N/A	N/A	Countermeasures
12c	What hardware and/or technology is/are effective in preserving muscle structure during a lunar mission?	N/A	3	N/A	Countermeasures
12d	What hardware and/or technology is/are effective in preserving muscle structure during a Mars mission?	N/A	N/A	3	Countermeasures
12e	Do countermeasure paradigms that counteract skeletal muscle atrophy processes during an ISS mission improve the structure-function properties of connective tissue systems?	2	N/A	N/A	Mechanisms

12f	Do countermeasure paradigms that counteract skeletal muscle atrophy processes during a lunar mission improve the structure-function properties of connective tissue systems?	N/A	2	N/A	Mechanisms
12g	Do countermeasure paradigms that counteract skeletal muscle atrophy processes during a Mars mission improve the structure-function properties of connective tissue systems?	N/A	N/A	2	Mechanisms
12h	Do countermeasures that minimize atrophy processes and strengthen skeletal muscle tendon properties that are performed in states of unloading prevent injury from occurring during a mission and upon return to weight bearing states (e.g., 1-G)?	1	1	1	Countermeasures
12i	What are the prescription guidelines and compliance factors needed for countermeasures (exercise, AG, etc.) during spaceflight to minimize susceptibility to skeletal muscle damage?	1	1	1	Countermeasures
12j	If a skeletal muscle injury occurs during spaceflight, what hardware and/or technology (e.g., strength measurement, muscle/connective tissue damage marker(s), pain surveys, diagnostic ultrasound) can be used to determine when it is safe for a crewmember to resume exercise or perform dynamic activities associated with the mission (e.g., EVA/exploration)?	1	1	1	Risk Assessment
12k	What are the assistance devices/technologies that can compensate for a skeletal muscle and/or associated connective tissue injury during spaceflight?	3	3	3	Countermeasures
12l	What prescription guidelines and compliance factors facilitate injury-free skeletal muscle rehabilitation in crewmembers returning from an ISS mission?	1	N/A	N/A	Countermeasures
12m	What prescription guidelines and compliance factors facilitate injury-free skeletal muscle rehabilitation in crewmembers returning from a lunar mission?	N/A	1	N/A	Countermeasures
12n	What prescription guidelines and compliance factors facilitate injury-free skeletal muscle rehabilitation in crewmembers returning from a Mars mission?	N/A	N/A	1	Countermeasures

Crosscutting Area: Human Health and Countermeasures (HHC)

Discipline:	***Sensory-Motor Adaptation***				
Risk:	***(13) Impaired Sensory-Motor Capability to Perform Operational Tasks During Flight, Entry, and Landing***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
13a	What are the physiological bases for spatial disorientation, perceptual illusions, and vertigo?	1	1	1	Mechanisms
13b	What combinations of visual, vestibular, and haptic cues cause spatial disorientation, perceptual illusions, and vertigo during and after g-transitions?	2	2	2	Mechanisms
13c	Can g-transition-related spatial disorientation, perceptual illusions, and vertigo be predicted from mathematical models?	3	3	3	Risk Assessment
13d	What individual physiological and behavioral characteristics contribute to the large inter-individual differences in neurovestibular symptoms and signs?	1	1	1	Mechanisms, Risk Assessment
13e	What individual physiological and behavioral characteristics will best predict susceptibility and adaptability?	3	3	3	Mechanisms, Risk Assessment
13f	What is the physiological basis for context-specific-adaptation?	1	1	1	Mechanisms
13g	To what extent can neurovestibular adaptation to weightlessness and/or artificial gravity take place in context-specific fashion, so crewmembers can be adapted to multiple environments and switch between them without suffering disorientation or motion sickness?	2	2	2	Risk Assessment
13h	What preflight training techniques (e.g., virtual reality simulations, parabolic flight) can be used to alleviate the risks of spatial disorientation, perceptual illusions, and vertigo as astronauts launch, enter, and adapt to 0-G?	2	2	2	Countermeasures
13i	What in-flight training techniques (e.g., virtual reality simulations, treadmill with vibration isolation system, artificial gravity) can be used to alleviate the risks of vertigo, disorientation, and perceptual illusions as astronauts land and (re)adapt to Earth, Moon, or Mars gravity?	3	3	3	Countermeasures
13j	Is adaptation to the lunar gravity environment sufficient to reduce incidence of landing vertigo upon return to Earth?	3	3	N/A	Risk Assessment
13k	What artificial gravity exposure regimens (g-level, angular velocity, duration, and repetition) will ameliorate the physiological and vestibular deconditioning associated with	N/A	5	5	Countermeasures

	hypogravity during transit phases of a mission in order to increase the capability to perform operational tasks during flight, entry and landing?				
13l	What level of supervisory control will mitigate the landing vertigo risk in landing on the Moon, Mars, and Earth?	4	4	4	Countermeasures

Crosscutting Area:	***Human Health and Countermeasures (HHC)***
Discipline:	***Sensory-Motor Adaptation***
Risk:	***(14) Impaired Sensory-Motor Capability to Perform Operational Tasks After Landing and Throughout Re-Adaptation***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
14a	What are the physiological bases for disruption of balance, locomotion, and eye-head coordination following g-transitions?	1	1	1	Mechanisms
14b	Can disruption of balance, locomotion, and eye-head coordination following g-transitions be predicted from mathematical models?	3	3	3	Risk Assessment
14c	What individual physiological and behavioral characteristics contribute to the large inter-individual differences in neurovestibular symptoms and signs?	1	1	1	Mechanisms, Risk Assessment
14d	What individual physiological and behavioral characteristics will best predict susceptibility and adaptability?	3	3	3	Mechanisms, Risk Assessment
14e	What is the physiological basis for context-specific-adaptation?	1	1	1	Mechanisms
14f	How can voluntary head movements during entry and landing be used to accelerate re-adaptation?	3	3	3	Countermeasures
14g	What in-flight training techniques (e.g., virtual reality simulations, treadmill with vibration isolation system, artificial gravity) can be used to alleviate the risks of impaired balance control and movement coordination as astronauts land and (re)adapt to Earth, Moon, or Mars gravity?	3	3	3	Countermeasures
14h	Is adaptation to the lunar gravity environment sufficient to reduce incidence of sensory-motor balance and coordination problems upon return to Earth?	N/A	TBD	N/A	Risk Assessment
14i	What artificial gravity exposure regimens (g-level, angular velocity, duration, and repetition) will ameliorate the physiological and vestibular	N/A	TBD	TBD	Countermeasures

	deconditioning associated with hypogravity during surface operation phases of a mission?				
14j	What artificial gravity exposure regimens (g-level, angular velocity, duration, and repetition) will ameliorate the physiological and vestibular deconditioning associated with hypogravity during transit phases of a mission in order to increase the capability to perform operational tasks after landing and throughout readaptation?	N/A	N/A	TBD	Countermeasures
14k	How can traditional clinical vestibular rehabilitation techniques be employed to usefully accelerate readaptation following g-transitions?	TBD	TBD	TBD	Countermeasures
14l	What objective assessment techniques can be used to determine crew readiness to return to normal activities following g-transitions?	TBD	TBD	TBD	Risk Assessment
14m	How can preflight or in-flight sensory-motor training or sensory aids improve post-landing postural and locomotor control and orthostatic tolerance?	TBD	TBD	TBD	Countermeasures
14n	To what extent can crewmembers "learn how to learn" by adapting to surrogate sensory-motor rearrangements?	TBD	TBD	TBD	Countermeasures
14o	What are the relative contributions of sensory-motor adaptation, neuromuscular deconditioning, and orthostatic intolerance to postflight neuro-motor coordination, ataxia, and locomotion difficulties?	TBD	TBD	TBD	Mechanisms, Risk Assessment
14p	What posture, locomotion, and gaze deficits result from transition to lunar gravity (1/6-G) or Mars gravity (3/8-G)?	TBD	TBD	TBD	Risk Assessment

Crosscutting Area:	***Human Health and Countermeasures (HHC)***
Discipline:	***Sensory-Motor Adaptation***
Risk:	***(15) Motion Sickness***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
15a	What are the physiological mechanisms that trigger vomiting in space motion sickness?	1	1	1	Mechanisms
15b	What is the physiological basis of the emetic linkage between vestibular and emetic centers?	2	2	2	Mechanisms
15c	What individual physiological and behavioral characteristics contribute to the large inter-individual differences in neurovestibular symptoms and signs?	1	1	1	Mechanisms, Risk Assessment
15d	What individual physiological and	3	3	3	Mechanisms, Risk

	behavioral characteristics will best predict susceptibility and adaptability?				Assessment
15e	What is the physiological basis for context-specific-adaptation?	1	1	1	Mechanisms
15f	To what extent can neurovestibular adaptation to weightlessness and/or artificial gravity take place in context-specific fashion, so crewmembers can be adapted to multiple environments and switch between them without suffering disorientation or motion sickness?	3	3	3	Risk Assessment
15g	What preflight training techniques (e.g., virtual reality simulations, parabolic flight) can be used to alleviate the risks of space motion sickness?	4	4	4	Countermeasures
15h	What in-flight training techniques (e.g., virtual reality simulations, treadmill with vibration isolation system, artificial gravity) can be used to alleviate the risks of space motion sickness as astronauts land and (re)adapt to Earth, Moon, or Mars gravity?	4	4	4	Countermeasures
15i	Is adaptation to the lunar gravity environment sufficient to reduce incidence of motion sickness upon return to Earth?	N/A	4	N/A	Countermeasures, Risk Assessment
15j	How does susceptibility to motion sickness due to Coriolis forces and cross-coupled canal stimuli vary as a function of g-levels between 0-G and 1-G, and also on RPM, radius, and head orientation during AG?	N/A	1	1	Risk Assessment
15k	What are the best methods for quantifying the symptoms and signs of motion sickness and associated performance decrements and drug side effects in a non-intrusive way?	2	2	2	Risk Assessment
15l	What better ways can be found to administer anti-motion sickness drugs to provide more rapid and reliable relief, with fewer objectionable side effects?	3	3	3	Countermeasures
15m	Do scopolamine and promethazine prevent or impair sensory-motor adaptation to 0-G?	4	4	4	Countermeasures, Mechanisms
15n	What new drugs will more specifically prevent nausea, fatigue, memory and vigilance deficits without side effects?	4	4	4	Countermeasures
15o	Can drugs be developed to effectively block the emetic linkage without unacceptable side effects?	4	4	4	Countermeasures, Mechanisms
15p	Can operationally practical, non-pharmacologic techniques be developed that are effective against motion sickness?	4	4	4	Countermeasures
15q	Is lunar gravity (1/6-G) or Mars gravity (3/8-G) adequate to prevent all cases of	4	4	4	Risk Assessment

	motion sickness?				

Crosscutting Area:	***Human Health and Countermeasures (HHC)***
Discipline:	***Nutrition***
Risk:	***(16) Inadequate Nutrition***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
16a	What are the nutritional requirements for extended stay ISS missions, including (but not limited to): calories, protein, calcium, iron, antioxidants, iodine, vitamin D, sodium, potassium?	1	1	1	Countermeasures
16b	What are the potential impacts of countermeasures on nutritional requirements or nutritional status?	1	1	1	Countermeasures
16c	What are the decrements in nutritional status due to long-term LEO, lunar, and exploration missions?	1	1	1	Countermeasures, Risk Assessment
16d	What are the means of monitoring nutritional status during the mission?	3	3	3	Medical Diagnosis & Treatment, Risk Assessment
16e	What monitoring (biochemical, anthropometric, clinical assessments) during rehabilitation is required?	3	3	3	Medical Diagnosis & Treatment
16f	What level of dietary counseling is needed for crewmembers during rehabilitation?	3	3	3	Countermeasures
16g	Can general nutrition, or specific nutrient countermeasures, mitigate the negative effects of spaceflight on bone, muscle, cardiovascular and immune systems, and protect against damage from radiation?	1	1	1	Countermeasures
16h	What is the role of adequate nutrition/weight maintenance on crew health (specifically bone, muscle and cardiovascular adaptation)?	1	2	1	Mechanisms
16i	What level of dietary counseling is needed for crewmembers pre-flight?	1	2	1	Countermeasures
16j	How does on-orbit exercise affect nutritional requirements and vice versa?	1	2	1	Countermeasures
16k	Can general nutrition, or specific nutrient countermeasures, mitigate radiation-induced carcinogenesis or cataractogenesis?	1	1	1	Countermeasures, Risk Assessment
16l	Are there long-term effects of disease risk post-flight, and can nutritional countermeasures be preventative?	1	2	1	Countermeasures, Risk Assessment

Crosscutting Area:	***Autonomous Medical Care (AMC)***
Discipline:	***Clinical Capabilities***
Risk:	***(17) Monitoring and Prevention***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
	Health Tracking				
17a	What are the key parameters for health screening and early detection?	4	2	1	Medical Diagnosis & Treatment
17b	What resources and technologies are required for routine health monitoring, including examination, laboratory, imaging and adaptation for operation in reduced-G environments?	4	2	1	Medical Diagnosis & Treatment
17c	What diagnostic imaging technologies and procedures need to be developed and/or adapted to support the primary, secondary and tertiary prevention of illness and injury?	3	2	1	Medical Diagnosis & Treatment
17d	What parameters and sensors are needed to monitor health and performance in crewmembers performing EVA?	4	2	2	Medical Diagnosis & Treatment
17e	What are the investigations needed to discriminate between terrestrial and spaceflight norms in order to allow early detection of illness and injury?	3	2	2	Medical Diagnosis & Treatment
17f	What is space-normal physiology?	4	3	3	Medical Diagnosis & Treatment
17g	What are the signs, symptoms or abnormal examination findings (including laboratory) associated with illness and injury in reduced-G?	TBD	TBD	TBD	Medical Diagnosis & Treatment
17h	How do alterations in spaceflight-associated physiology interact across body systems?	4	3	3	Medical Diagnosis & Treatment
17i	What are the appropriate informatics tools to automate crew health monitoring in order to free-up crew time (i.e. prompting screening and evaluations, off-nominal value detection, intelligent diagnostic work-up)?	2	1	1	Medical Diagnosis & Treatment
	Prophylaxis/Disease Prevention				
17j	What are the ideal set of nutritional and medical prophylaxes, and primary and secondary preventive measures to reduce the risk of space illness (such as medical countermeasures for known conditions - e.g., bisphosphonates for loss of BMD)?	3	2	2	Countermeasures
17k	What are the primary, secondary, and tertiary prevention strategies needed to mitigate the risk of anticipated environmental exposures to radiation and toxic substances (i.e. shielding, nutritional and medical prophylaxis such as agents to augment cellular defenses, immune surveillance, etc.)?	2	1	1	Countermeasures
17l	What are the essential technologies, resources, procedures, skills and training necessary to provide effective primary	4	3	2	Countermeasures

	prevention strategies to mitigate each of the conditions listed in the SMCCB-approved Space Medicine Condition List (catalogued in the online Patient Condition Database)?				
17m	What are the essential technologies, resources, procedures, skills and training necessary to provide effective secondary prevention strategies to mitigate each of the conditions listed in the SMCCB-approved Space Medicine Condition List (catalogued in the online Patient Condition Database)?	4	3	2	Countermeasures

Crosscutting Area:	***Autonomous Medical Care (AMC)***				
Discipline:	***Clinical Capabilities***				
Risk:	***(18) Major Illness and Trauma***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
18a	What are the essential technologies, resources, procedures, skills, and training necessary to provide effective prevention strategies to mitigate each of the conditions listed in the SMCCB-approved Space Medicine Condition List (catalogued in the online Patient Condition Database)?	3	1	1	Medical Diagnosis & Treatment
18b	What are the technologies for employing decision support techniques for diagnostic assistance of the crew medical personnel, emphasizing autonomy in decision-making from ground resources and based on known spaceflight illnesses and injuries and expedition analog experience?	2	1	1	Medical Diagnosis & Treatment
18c	What are the appropriate roles and resources required for telemedical consultation for the diagnosis and management of major illnesses?	3	2	1	Medical Diagnosis & Treatment
18d	What resources are required for telemedical consultation, diagnosis, and management of major trauma?	3	2	1	Medical Diagnosis & Treatment
	Major Illness Treatment				
18e	What are the resources, procedures, and technologies required for treatment of major illnesses, emphasizing autonomy from ground resources and based on known spaceflight illnesses, injuries, and expedition analog experience, and how might they be adapted for reduced-G operations?	2	1	1	Medical Diagnosis & Treatment
18f	What are the resources and procedures needed to perform basic and advanced	3	1	1	Medical Diagnosis & Treatment

	management of trauma?				
18g	What are the specific techniques, resources, protocols, training curricula, skills, and equipment (technology) necessary to implement palliative care protocols for in-flight use?	4	2	1	Medical Diagnosis & Treatment
18h	What are effective management strategies for chronic pain in reduced-G (pharmacologic and non-pharmacologic)?	TBD	TBD	TBD	Medical Diagnosis & Treatment
18i	What procedures and protocols are necessary for rehabilitation after an acute medical illness or trauma?	4	3	1	Medical Diagnosis & Treatment
18j	What are effective management strategies for acute pain in reduced-G (pharmacologic and non-pharmacologic)?	TBD	TBD	TBD	Medical Diagnosis & Treatment
18k	What are the nutritional requirements for adequate red cell production in microgravity? What are the contributory factors and how do they inter-relate in the development of space anemia (radiation, unloading, nutrition, fluid shift, changes in sex hormones, etc.)?	2	2	2	Countermeasures
18l	How can aplastic anemia be treated during space missions?	5	5	3	Medical Diagnosis & Treatment
18m	What are the appropriate synergistic and alternative management strategies for reducing the morbidity of major illnesses during spaceflight?	TBD	TBD	TBD	Medical Diagnosis & Treatment
18n	What is the most effective means of conducting life support operations in the spaceflight milieu, to include identification and modification of the resources and procedures for reduced-G?	3	2	1	Medical Diagnosis & Treatment
18o	What are the optimal resources and procedures for post-resuscitation management of the ill/injured crewmember and modify for reduced-G operations?	2	1	1	Medical Diagnosis & Treatment
18p	What is the most effective pre-EVA Decompression Sickness (DCS) prevention strategy to include pre-breathe with various gases, exercise and other medical measures?	5	TBD	TBD	Countermeasures
18q	What are the appropriate screening procedures to minimize predispositions for DCS?	4	TBD	TBD	Countermeasures
18r	What are the resources and techniques for early diagnosis of DCS signs and symptoms, including the use of Doppler U/S and other bubble detection technologies?	4	TBD	TBD	Medical Diagnosis & Treatment
18s	What are the best methods for predicting DCS risk and for reducing the risk, based on understanding of the physiological mechanism for bubble formation and	4	TBD	TBD	Risk Assessment

	propagation, employing best available knowledge from flight and analog environment experience?				
18t	What are the most effective yet safe, and energy- and space-efficient means of managing DCS in the spaceflight milieu, including the use of hyperbaric oxygen delivery and other promising technology, and how might they be adapted for reduced-G operations?	3	2	1	Medical Diagnosis & Treatment
18u	What is the actual risk of space-related DCS? (de novo physiological causes and acute environmental insult - e.g., leaking module or damaged EMU etc.)	3	3	3	Medical Diagnosis & Treatment
18v	What are the operational and medical impacts of off-nominal performance of DCS countermeasures?	4	3	3	Countermeasures
18w	What are the risk factors that can increase the likelihood of DCS, such as the presence of Patent Foramen Ovale (PFO)?	4	3	2	Risk Assessment
18x	What is the likelihood of surviving an acute environmental insult severe enough to cause damage to the vehicle or spacesuit?	2	2	2	Risk Assessment
18y	Is it possible and what are the DCS risk mitigation options for interplanetary EVA (e.g., moon and Mars) given that a tri-gas breathing mixture including argon is present?	4	4	4	Countermeasures
18z	What is the role of individual susceptibility, age and gender on the risk of DCS during NASA operations involving decompression?	4	3	3	Risk Assessment
18aa	What are the available and new technologies needed to provide hyperbaric treatment options on the ISS and future habitats (or vehicles) beyond LEO (e.g., on the moon or Mars)?	3	2	1	Medical Diagnosis & Treatment
18ab	What is the correlation between the detection/existence of gas phase creation in the bloodstream and development of clinically significant DCS?	4	3	3	Mechanisms
18ac	What are the monitoring, prevention, and treatment methods for clinical effects of acute, excessive, radiation exposure?	3	2	1	Medical Diagnosis & Treatment
18ad	What are the signs and symptoms secondary to radiation and toxic chemical exposure in reduced-G environments?	2	1	1	Risk Assessment
18ae	What are the resources and procedures for the mitigation of toxic exposures?	3	1	1	Countermeasures
18af	What primary prevention strategies (such as crew screening and selection criteria) should be developed and implemented to identify individuals who are at increased	3	2	2	Countermeasures

	risk for developing hypersensitivity or allergies to spaceflight compounds, exposures, or payloads?				
18ag	What secondary prevention strategies (i.e. countermeasures) should be developed and implemented to prevent adverse reactions to toxic exposures (e.g., sleep, nutritional, medications, stress reduction, shielding, protective equipment, etc.)?	3	2	2	Countermeasures
18ah	What resources and procedures are needed for the surgical management of major illness, injury, and trauma?	3	1	1	Medical Diagnosis & Treatment
18ai	What are the appropriate roles and resources required for telemedical consultation for the surgical management of major illnesses?	3	2	1	Medical Diagnosis & Treatment
18aj	What are the issues surrounding wound care, and how are they best resolved?	4	2	2	Countermeasures, Medical Diagnosis & Treatment
18ak	What are effective regional and local anesthesia strategies in reduced G?	TBD	TBD	TBD	Medical Diagnosis & Treatment
18al	What methods and new technologies are needed for blood replacement therapy in space?	3	2	1	Medical Diagnosis & Treatment
	Medical Waste Management				
18am	What are the most effective means of management and disposal of medical waste within the surgical milieu?	2	1	1	Medical Diagnosis & Treatment

Crosscutting Area:	***Autonomous Medical Care (AMC)***				
Discipline:	***Clinical Capabilities***				
Risk:	***(19) Pharmacology of Space Medicine Delivery***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
	Pharmacodynamics/Pharmacokinetics				
19a	What are the effects of spaceflight and reduced-G on the absorption, distribution, metabolism, clearance, excretion, clinical efficacy, side effects and drug interactions for medications used in primary, secondary and tertiary prevention of conditions stated in the Space Medicine Condition List?	2	2	1	Medical Diagnosis & Treatment
19b	How should the crew and medical team be trained and prepared to recognize and deal with side effects and interaction effects of commonly used medications?	3	3	2	Medical Diagnosis & Treatment
19c	What diagnostic, therapeutic and laboratory technologies are necessary to predict (model) and manage medication side effects, interactions and toxicity during spaceflight?	3	3	3	Medical Diagnosis & Treatment

19d	What effect does space adaptation have on drug bio-availability and how can efficacy be enhanced?	2	2	1	Medical Diagnosis & Treatment
	Drug Stowage/Utilization/Replenishment				
19e	What is the effect of long-duration spaceflight on drug stability, and what measures can be employed to extend the duration of drug efficacy?	3	1	1	Medical Diagnosis & Treatment
19f	What are the appropriate on-orbit/on-station means of drug and intravenous (IV) fluid replenishment appropriate for space operations?	3	1	1	Medical Diagnosis & Treatment
19g	What are biomedical models for drug efficacy?	4	3	3	Medical Diagnosis & Treatment
	Drug Use Optimization				
19h	What are the optimal dosages and routes of administration for spaceflight/reduced-G clinical effectiveness?	3	2	2	Medical Diagnosis & Treatment
19i	What are efficient means of monitoring drug levels for therapeutic effect and toxicity to minimize cross-reaction and negative synergy?	4	3	3	Medical Diagnosis & Treatment

Crosscutting Area:	***Autonomous Medical Care (AMC)***				
Discipline:	***Clinical Capabilities***				
Risk:	***(20) Ambulatory Care***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
	Minor Illness Diagnosis				
20a	What are the resources for establishing the diagnosis of minor illnesses, emphasizing autonomous decision-making, based on known spaceflight illnesses, injuries, and expedition analogs? How might they be adapted to reduced-G operations?	4	2	1	Medical Diagnosis & Treatment
20b	What are the appropriate roles and resources required for telemedical consultation for the diagnosis and management of minor illnesses?	4	3	2	Medical Diagnosis & Treatment
	Minor Illness Management				
20c	What are the resources and procedures required for treatment of minor illnesses, emphasizing autonomy from ground resources and based on known spaceflight illnesses and injuries and expedition analog experience, and how might they be adapted for reduced-G operations?	4	3	2	Medical Diagnosis & Treatment
20d	What are the appropriate synergistic and alternative management strategies for reducing the morbidity of minor illnesses during spaceflight?	TBD	TBD	TBD	Medical Diagnosis & Treatment

	Minor Trauma Management				
20e	What are the resources and procedures required for the treatment of minor trauma, emphasizing autonomous decision-making, based on known spaceflight illnesses, injuries, and expedition analogs? How might they be adapted to reduced-G operations?	3	1	1	Medical Diagnosis & Treatment

Crosscutting Area:	***Autonomous Medical Care (AMC)***				
Discipline:	***Clinical Capabilities***				
Risk:	***(21) Rehabilitation on Mars***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
21a	What are the primary, secondary and tertiary preventive strategies needed to ensure post-landing performance for a Mars mission?	N/A	N/A	1	Countermeasures, Medical Diagnosis & Treatment
21b	What are the essential technologies, resources, protocols, skills and training necessary for post landing rehabilitation (including psychological, cardiovascular, neurosensory, musculoskeletal and nutritional)?	N/A	N/A	1	Medical Diagnosis & Treatment

Crosscutting Area:	***Autonomous Medical Care (AMC)***				
Discipline:	***Clinical Capabilities***				
Risk:	***(22) Medical Informatics, Technologies, and Support Systems***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
22a	What decision support technologies are needed to support clinical care?	4	2	1	Medical Diagnosis & Treatment
22b	What informatics systems and technology are needed, both for crew and ground support, to optimize medical care?	3	1	1	Medical Diagnosis & Treatment
22c	What are the impacts of communication latency on the ability to provide primary, secondary and tertiary prevention during spaceflight?	4	4	1	Medical Diagnosis & Treatment

Crosscutting Area:	***Autonomous Medical Care (AMC)***				
Discipline:	***Clinical Capabilities***				
Risk:	***(23) Medical Skill Training and Maintenance***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
23a	What are the necessary clinical skills/knowledge for a space medicine	4	1	1	Medical Diagnosis & Treatment

	physician?				
23b	How can the clinical skills and knowledge of space medical care providers be maintained during missions?	2	2	1	Medical Diagnosis & Treatment
23c	What is the optimum crew complement (size, skill sets, etc.) to provide the appropriate medical care for the primary, secondary and tertiary care for the conditions in the Space Medicine Condition List?	4	3	1	Countermeasures
23d	What techniques can be used to train and maintain the skills of the crew medical personnel to perform specific medical procedures when needed?	3	1	1	Countermeasures

Crosscutting Area:	***Behavioral Health and Performance (BHP)***
Discipline:	***Behavioral Health & Performance and Space Human Factors (Cognitive)***
Risk:	***(24) Human Performance Failure Due to Poor Psychosocial Adaptation***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
24a	What are the fundamental behavioral and social stressors during long-duration missions that will most likely affect crew performance, both individual and team and how can they be tested in Earth analogue environments, to be eliminated or accommodated?	1	1	1	Mechanisms
24b	What factors contribute to the breakdown of individual and team performance and team coordination with mission support with regard to scheduling, prioritization of work activities and control of timelines?	1	1	1	Risk Assessment
24c	What behaviors, experiences, personality traits and leadership styles in crewmembers most contribute to optimal performance? How are these factors related to performance of individuals and teams?	2	2	2	Mechanisms
24d	What criteria can be identified during the selection process and be used to select and assemble the best teams for long-duration missions?	2	2	2	Countermeasures
24e	What factors in crew design, composition, dynamics and size will best enhance the crew's ability to live and work in the space environment? How are these factors different from shorter duration missions?	2	2	2	Countermeasures
24f	How can attitudes and behaviors of agency management, ground controllers, crewmembers and their families be	2	2	2	Countermeasures

	modified to maintain and improve individual and group performance?				

Crosscutting Area:	***Behavioral Health and Performance (BHP)***
Discipline:	***Behavioral Health & Performance and Space Human Factors (Cognitive)***
Risk:	***(25) Human Performance Failure Due to Neurobehavioral Problems***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
25a	What are the best select-out tools of astronaut candidates and best select-out tools for selection of individuals to teams for specific missions to avoid possible neuropsychiatric and psychological incompatibility with the mission and fellow team members?	1	1	1	Countermeasures
25b	What are the long-term effects of exposure to the space environment (microgravity, isolation, stress) on human neurocognitive and neurobiological functions (from cellular to behavioral levels of the nervous system)?	2	2	2	Mechanisms
25c	What are the long-term effects of exposure to the space environment on human emotion and psychological responses, including emotional reactivity, stress responses, long-term modulation of mood and vulnerability to affective and cognitive disorders?	3	3	3	Mechanisms
25d	What objective techniques and technologies validly and reliably identify when astronauts are experiencing distress that compromises their performance capability in space?	1	1	1	Medical Diagnosis & Treatment
25e	What are the best behavioral, technological and pharmacological countermeasures for managing cognitive dysfunction, neuropsychiatric and behavior problems in space?	3	3	3	Countermeasures
25f	What are the best behavioral, psychological, technological and pharmacological countermeasures for managing emotional and stress-related problems in space?	3	3	3	Countermeasures
25g	What are the best techniques and technologies for identification and treatment of cognitive disorders, neuropsychiatric and behavior problems in space?	4	4	4	Medical Diagnosis & Treatment
25h	What are the strategies for psychological stress management, and maintaining the morale and acceptable functioning and	3	1	1	Countermeasures

	safety of remaining crewmembers after an adverse event during a mission?				

Crosscutting Area:	***Behavioral Health and Performance (BHP)***
Discipline:	***Behavioral Health & Performance and Space Human Factors (Cognitive)***
Risk:	***(26) Mismatch between Crew Cognitive Capabilities and Task Demands***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
26a	What crew size and composition is required to provide the amount of information, variety of skills, etc. required to accomplish the reference mission?	2	1	1	Countermeasures
26b	What is required to counteract the negative effects of communications lags on human performance?	1	1	1	Countermeasures, Risk Assessment
26c	What information systems, interface designs, intelligent systems and other tools to enable autonomy are required to enable human performance to be maintained at an acceptable level over the reference missions? (Shared - Integrated Testing supports)	2	1	1	Risk Assessment
26d	What types and techniques of training are required and within what timeframes, to enable the crewmembers to accomplish the mission with increased effectiveness, efficiency and safety?	1	1	1	Countermeasures
26e	What principles of task design, procedures, job aids and tools and equipment, are required to enable crewmembers to accomplish nominal and emergency perceptual and cognitive tasks?	2	1	1	Countermeasures
26f	How can crewmembers and ground support personnel detect and compensate for decreased cognitive readiness to perform?	1	1	1	Countermeasures
26g	What scheduling constraints are required to reduce the risk of human error due to fatigue? (shared with Sleep and Circadian Rhythm)	2	2	2	Countermeasures
26h	What tools and techniques will maintain the crew's situational awareness at a level sufficient to perform nominal and emergency tasks?	2	1	1	Countermeasures
26i	What characteristics of equipment, tool and computer displays; instructions, procedures, labels and warning; and human-computer interaction designs will maintain critical sensory and cognitive	2	2	2	Countermeasures

	capabilities?				
26j	What approaches to human computer interactions will maintain crew critical capabilities to assess, control and communicate?	2	2	2	Countermeasures
26k	What decision-support systems are required to aid crew decision-making?	2	2	2	Countermeasures
26l	What design considerations are needed to accommodate effects of changes in gravity on perception (Launch, lunar landing, lunar launch, Earth return)?	N/A	1	1	Countermeasures

Crosscutting Area:	***Behavioral Health and Performance (BHP)***
Discipline:	***Behavioral Health & Performance and Space Human Factors (Cognitive)***
Risk:	***(27) Human Performance Failure Due to Sleep Loss and Circadian Rhythm Problems***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
27a	What are the acute and long-term effects of exposure to the space environment on biological rhythmicity on sleep architecture, quantity and quality and their relationship to performance capability?	1	1	1	Mechanisms
27b	Which countermeasures or combination of behavioral and physiological countermeasures will optimally mitigate specific performance problems associated with sleep loss and circadian disturbances during the reference missions?	1	1	1	Countermeasures
27c	What are the long-term effects of countermeasures employed to mitigate pre, - in- and post-flight performance problems with sleep loss and circadian disturbances?	3	4	2	Countermeasures
27d	What are the best methods for in-flight monitoring of the status of sleep, circadian functioning and light exposures for assessing the effects of sleep loss and circadian dysrhythmia on performance capability that are also portable and non-intrusive in the spaceflight environment? (e.g., actigraphy)	2	2	2	Medical Diagnosis & Treatment, Risk Assessment
27e	What work, workload and sleep schedule(s) will best enhance crew performance and mitigate adverse effects of the space environment?	1	1	1	Countermeasures
27f	What individual biological and behavioral characteristics will best predict successful adaptation to long-term spaceflight of sleep, circadian physiology and the neurobehavioral performance functions	4	5	1	Countermeasures

	they regulate?				
27g	What mathematical and computational models should be used to predict performance associated with sleep-wake, schedule, work history, light exposure and circadian rhythm status and also provide guidelines for successful countermeasure strategies?	1	1	1	Countermeasures, Risk Assessment

Crosscutting Area:	***Radiation Health (RH)***				
Discipline:	***Radiation***				
Risk:	***(28) Carcinogenesis***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
28a	What are the probabilities for increased carcinogenesis from space radiation as a function of NASA's operational parameters (age at exposure, age, latency, gender, tissue, mission, radiation quality, dose rate and exposure protraction)?	1	1	1	Risk Assessment
28b	How can tissue specific probabilities for increased carcinogenesis risk from space radiation be best evaluated? What molecular, genetic, epigenetic, abscopal (effect that irradiation of a tissue has on remote non-irradiated tissue), and other factors contribute to the tissue specificity of carcinogenic risk?	1	1	1	Medical Diagnosis & Treatment
28c	How can the individual's sensitivity to radiation carcinogenesis be estimated?	2	2	1	Risk Assessment
28d	How can effective biomarkers of carcinogenic risk from space radiation be developed and validated?	3	3	2	Risk Assessment
28e	What are the most effective biomedical or dietary countermeasures to mitigate cancer risks? By what mechanisms are the countermeasures expected to work and do they have the same efficiency for low- and high-LET radiation?	3	3	1	Countermeasures
28f	How can animal models (including genetic models such as those developed by gene targeting or the use of other transgenic approaches) of carcinogenesis be developed to improve estimates of cancers from space radiation and what longitudinal studies are needed?	2	2	1	Risk Assessment
28g	What improvements can be made to quantitative procedures or theoretical models in order to extrapolate molecular, cellular, or animal results to determine the risks of specific cancers in astronauts? How can human epidemiology data best support these procedures or models?	3	3	2	Risk Assessment

28h	Are there significant combined effects from other spaceflight factors (microgravity, stress, altered circadian rhythms, changes in immune responses, viral reactivation etc.) that modify the carcinogenic risk from space radiation?	5	5	3	Risk Assessment
28i	What are the probabilities that space radiation will produce DNA damage at specific sites, including clustered DNA damage? What is the likelihood that DNA damage will increase the risk of carcinogenesis?	3	3	2	Mechanisms, Risk Assessment
28j	What mechanisms modulate radiation damage at the molecular level (e.g., repair, errors in repair, signal transduction, gene amplification, bystander effects, tissue microenvironment, etc.) that significantly impact the risk of cancers, modulate the expression of radiation damage and decrease the radiation risk, and how can the understanding of mechanisms be used to predict carcinogenic risks from space radiation?	2	2	1	Mechanisms
28k	What space validation experiments could improve estimates of carcinogenic risks for long-term deep-space missions?	5	5	3	Risk Assessment
28l	What are the most effective shielding approaches to mitigate cancer risks?	1	1	1	Countermeasures
28m	What new materials or active shielding methods can be used for reducing space radiation cancer risks?	1	1	1	Countermeasures
28n	What are the most effective approaches to integrate radiation shielding analysis codes with collaborative engineering design environments used by spacecraft and planetary habitat design efforts?	4	1	1	Countermeasures
28o	What is the most effective approach to use data from robotic Mars probes on the atmospheric, soil, and magnetic properties of the red planet for estimating carcinogenesis risk, and designing effective shielding or biological countermeasures?	5	5	2	Countermeasures
28p	What are the critical nuclear interaction experimental data and predictive theoretical models needed to complete radiation shielding analysis codes in support of exploration spacecraft and planetary habitat designs?	5	2	1	Mechanisms

Crosscutting Area:	***Radiation Health (RH)***
Discipline:	***Radiation***

Risk:	***(29) Acute and Late CNS Risks***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
29a	Is there a significant probability that space radiation would lead to immediate or acute functional changes in the CNS due to a long-term space mission and if so what are the mechanisms of change?	3	3	1	Mechanisms, Risk Assessment
29b	Is there a significant probability that space radiation exposures would lead to long-term or late degenerative CNS risks? If so what are the mechanisms of change?	3	3	1	Mechanisms, Risk Assessment
29c	How does individual susceptibility including hereditary pre-disposition (Alzheimer's, Parkinson's, apoE) and prior CNS injury (concussion or other) alter significant CNS risks?	3	3	1	Risk Assessment
29d	What are the most effective biomedical or dietary countermeasures to mitigate CNS risks? By what mechanisms do the countermeasures work?	4	4	1	Countermeasures, Mechanisms
29e	How can animal models of CNS risks, including altered motor and cognitive function, behavioral changes and late degenerative risks be best used for estimating space radiation risks to astronauts?	4	3	1	Risk Assessment
29f	Are there significant CNS risks from combined space radiation and other physiological or spaceflight factors (e.g., bone loss, microgravity, immune-endocrine systems or other)?	5	5	3	Risk Assessment
29g	What are the molecular, cellular and tissue mechanisms of damage [DNA damage processing, oxidative damage, cell loss through apoptosis or necrosis, changes in the extra-cellular matrix, cytokine activation, inflammation, changes in plasticity, micro-lesion (clusters of damaged cells along heavy ion track) etc.] in the CNS?	4	3	1	Mechanisms
29h	What are the different roles of neural cell populations, including neuronal stem cells and their integrative mechanisms in the morphological and functional consequences of space radiation exposure?	2	2	1	Mechanisms
29i	Are there biomarkers for detecting damage or susceptibility to/for radiation-induced CNS damage?	4	3	2	Risk Assessment
29j	What quantitative procedures or theoretical models are needed to extrapolate molecular, cellular, or animal results to predict CNS risks in astronauts? How can human epidemiology data best	4	3	2	Risk Assessment

	support these procedures or models?				
29k	What are the most effective shielding approaches to mitigate CNS risks?	1	1	1	Countermeasures
29l	What space validation experiments could improve estimates of CNS risks for long-term deep-space missions?	5	5	3	Countermeasures

Crosscutting Area:	***Radiation Health (RH)***				
Discipline:	***Radiation***				
Risk:	***(30) Chronic and Degenerative Tissue Risks***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
30a	What are the probabilities for degenerative tissue risks from protons and HZE ions as a function of NASA's operational parameters (age at exposure, age and time after exposure, gender, tissue, mission, radiation quality, dose rate)?	2	2	1	Risk Assessment
30b	What are the mechanisms of degenerative tissues risks in the heart, circulatory, endocrine, digestive, lens and other tissue systems?	2	2	1	Mechanisms
30c	How can the latency period for degenerative tissue risks, including sub-clinical diseases, following space radiation exposures be estimated?	3	3	1	Risk Assessment
30d	What are the most effective biomedical or dietary countermeasures to degenerative tissue risks? By what mechanisms do the countermeasures work?	3	3	1	Countermeasures, Mechanisms
30e	What quantitative procedures or theoretical models are needed to extrapolate molecular, cellular, or animal results to predict degenerative tissue risks in astronauts? How can human epidemiology data best support these procedures or models?	4	4	2	Risk Assessment

Crosscutting Area:	***Radiation Health (RH)***				
Discipline:	***Radiation***				
Risk:	***(31) Acute Radiation Risks***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
31a	How can predictions of acute space radiation events be improved?	5	3	3	Risk Assessment
31b	Are there synergistic effects arising from other spaceflight factors (microgravity, stress, immune status, bone loss, damage to intestinal cells reducing their ability to	4	3	3	Risk Assessment

	absorb medication etc.) that modify acute risks from space radiation including modifying thresholds for such effects?				
31c	What are the molecular, cellular and tissue mechanisms of acute radiation damage (DNA damage processing, oxidative damage, cell loss through apoptosis or necrosis, cytokine activation, etc.)?	4	3	3	Mechanisms
31d	Does protracted exposure to space radiation modify acute doses from SPEs in relationship to acute radiation syndromes?	4	3	3	Risk Assessment
31e	What are the most effective biomedical or dietary countermeasures to mitigate acute radiation risks? By what mechanisms do the countermeasures work?	4	3	3	Countermeasures, Mechanisms
31f	What quantitative procedures or theoretical models are needed to extrapolate molecular, cellular, or animal results to predict acute radiation risks in astronauts? How can human epidemiology data best support these procedures or models?	4	3	3	Risk Assessment
31g	What are the most effective shielding approaches to mitigate acute radiation risks?	1	1	1	Countermeasures
31h	What are the most effective "storm shelter" shielding approaches to protect against large solar particle events in deep space or on planetary surfaces?	3	1	1	Countermeasures

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***				
Discipline:	***Advanced Environmental Monitoring & Control***				
Risk:	***(32) Monitor Air Quality***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
32a	What technologies can be used to detect slow, gradual changes in the chemical and microbial environment ?(work with Environmental Health)	1	1	1	Technologies
32b	What set of technologies and data can be used to quickly diagnose potentially hazardous events from chemical data?	1	1	1	Technologies
32c	How can environmental information be used to assist in-flight biomonitoring for health and performance of the astronauts (supporting Biomedical monitoring)?	3	3	3	Operations and Training
32d	What technologies must be developed to rapidly detect and address fire in space?	1	1	1	Technologies
32e	How can technology help ensure that appropriate responses to hazardous events are achieved in a timely manner?	2	2	2	Operations and Training, Technologies

32f	What set of technologies and data can be used to detect and diagnose hardware malfunction, in such systems as life support or in situ resource utilization by assessment of environmental (air, water, or surfaces) changes? (work with ALS)	2	2	2	Operations and Training, Technologies
32g	What technologies can detect both anticipated and unanticipated species and events?	1	1	1	Technologies

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***				
Discipline:	***Advanced Environmental Monitoring & Control***				
Risk:	***(33) Monitor External Environment***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
33a	What sensors are required to monitor hazardous conditions in the extra-vehicular environment? (work with AEVA)	1	1	1	Requirements/Specifications, Technologies

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***				
Discipline:	***Advanced Environmental Monitoring & Control***				
Risk:	***(34) Monitor Water Quality***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
34a	What technologies can be used to detect slow, gradual changes in the chemical and microbial environment? (work with ALS and Environmental Health)	1	1	1	Technologies
34b	What set of technologies and data can be used to quickly diagnose potentially hazardous events from chemical data?	1	1	1	Technologies
34c	How can technology help ensure that appropriate responses to hazardous events are achieved in a timely manner? (Needed for developing automated systems.)	2	2	2	Operations and Training, Technologies
34d	What set of technologies and data can be used to detect and diagnose hardware malfunction by assessment of environmental (air, water, or surfaces) changes? (work with ALS)	1	1	1	Operations and Training, Technologies
34e	What technologies can detect both anticipated and unanticipated species and events?	1	1	1	Technologies

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***
Discipline:	***Advanced Environmental Monitoring & Control***
Risk:	***(35) Monitor Surfaces, Food, and Soil***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
35a	What technologies can be used to detect slow, gradual changes in the chemical and microbial surface environment? (work with Environmental Health and ALS)	1	1	1	Technologies
35b	What set of technologies and data can be used to quickly diagnose potentially hazardous events from chemical data?	1	1	1	Operations and Training, Technologies
35c	What technologies are required to meet the radiation monitoring requirements of a mission?	2	1	1	Technologies
35d	What sample acquisition and preparation technologies can meet the requirements of the gaseous, aqueous and solid-phase matrices monitoring?	1	1	1	Operations and Training, Technologies
35e	What research is required to validate design approaches for multiphase flow for monitoring systems in varying gravity environments?	1	2	2	Requirements/Specifications

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***
Discipline:	***Advanced Environmental Monitoring & Control***
Risk:	***(36) Provide Integrated Autonomous Control of Life Support Systems***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
36a	How do we design an effective control system with flexibility, modularity, growth potential, anti-obsolescence and accommodate varied, new, & unknown test articles, taking advantage of standards? (work with Integrated Testing)	1	1	1	Requirements/Specifications
36b	How does a control system manage and plan for the long time constants of certain biological processes that lead to changes days, months later; and reconciles between discrete events, continuous processing and varying time constants? (work with Integrated Testing)	1	1	1	Operations and Training, Requirements/Specifications
36c	How do we assure that human situation awareness is at a high level when needed, while offloading the crew workload for most of the time? (work with SHFE and Integrated Testing)	2	2	2	Operations and Training, Requirements/Specifications
36d	How can a control system support strategic decisions; launch readiness/abort/return home decisions and procedures? (work with SHFE and Integrated Testing)	1	1	1	Operations and Training, Requirements/Specifications
36e	How can we develop real time prognostic capabilities to predict failures before they	1	1	1	Technologies

	occur and degradations before they have impact? (work with ALS and Integrated Testing)				
36f	How do we allocate efficiently and safely between space-based control and ground-based control? (work with SHFE and Integrated Testing)	1	1	1	Operations and Training, Requirements/Specifications
36g	In very large and complex systems, how can we synchronize system states across subsystems? (work with Integrated Testing)	1	1	1	Operations and Training, Requirements/Specifications
36h	How do we trade between buffers and controls to ensure safe and reliable system? (work with ALS and Integrated Testing)	1	1	1	Design Tools, Requirements/Specifications
36i	How can understanding process control help determine which sensors may be missing and where sensors should be placed? (work with Integrated Testing)	1	1	1	Design Tools, Requirements/Specifications

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***				
Discipline:	***Advanced Extravehicular Activity***				
Risk:	***(37) Provide Space Suits and Portable Life Support Systems***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
37a	What EVA system design and minimum prebreathe protocol can be developed to reduce the risk of decompression sickness?	N/A	1	1	Operations and Training, Requirements/Specifications
37b	What suit and PLSS technology must be developed to meet mission requirements for EVA mobility?	N/A	1	1	Technologies
37c	How do we protect against planetary surface dust through suit and airlock system design?	N/A	1	1	Requirements/Specifications, Technologies
37d	How do we protect against toxic fluids and contaminants?	2	2	2	Requirements/Specifications, Technologies
37e	How do we design space suits to fit multiple crewmembers of various sizes and shapes?	1	1	1	Design Tools, Requirements/Specifications
37f	How do we improve glove dexterity?	1	1	1	Technologies
37g	What technologies can be developed to provide passive or active thermal insulation in various environments, including deep-space and lunar vacuum?	N/A	1	1	Technologies
37h	What technologies must be developed to meet mission non-venting and non-contaminating requirements?	N/A	2	2	Operations and Training, Technologies
37i	How do we provide and manage increased information to EVA crewmembers, including suit parameters, systems status, caution and warning,	N/A	2	2	Requirements/Specifications

	video, sensor data, procedures, text, and graphics?				
37j	How do we achieve EVA and robotic interaction and cooperation?	N/A	1	1	Requirements/Specifications, Technologies
37k	What biomedical sensors are needed to enhance safety and performance during EVAs?	4	2	2	Requirements/Specifications, Technologies
37l	How can space suit design accommodate a crewmember's physical changes from long-duration exposure to microgravity?	4	1	1	Technologies
37m	What technology can be developed to monitor EVA crewmember thermal status and provide auto-thermal control under both nominal operating and emergency conditions?	N/A	1	1	Requirements/Specifications, Technologies
37n	Can a practical EMU containment receptacle for emesis be developed? If a vomiting episode occurs, is there a way of refurbishing the suit during the mission? How can suit life support systems be designed to be more resistant to vomiting episode?	1	1	1	Requirements/Specifications, Technologies

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***				
Discipline:	***Advanced Food Technology***				
Risk:	***(38) Maintain Food Quantity and Quality***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
38a	What procedures (e.g., storage, processing, preparation, clean-up), such as HACCP, need to be developed to assure a safe food system?	1	1	1	Operations and Training, Requirements/Specifications
38b	What are the allowable limits of microbial and chemical contamination in the food?	1	1	1	Requirements/Specifications
38c	How does space radiation affect the functionality and nutritional content of the crops and stored staple ingredients for food processing?	N/A	1	1	Requirements/Specifications
38d	What food processing technologies are required when using crops and stored staple ingredients to ensure a food system that is nutritious, safe and acceptable?	N/A	1	1	Requirements/Specifications, Technologies
38e	What food packaging materials will provide the physical and chemical attributes, including barrier properties, to protect the food from the outside environment and assure the 3-5 year shelf life?	1	1	1	Technologies
38f	What food packaging material will be biodegradable, easily processed, or be lighter in mass than the current packaging	1	1	1	Requirements/Specifications, Technologies

	and can still provide the physical and chemical attributes including barrier properties to protect the food from the outside environment and assure the 3-5 year shelf life?				
38g	What food preservation technologies will provide prepackaged food items with a shelf life of 3-5 years?	2	2	2	Requirements/Specifications, Technologies
38h	What are the impacts of reduced Gravity and atmospheric pressure on the food processing activities?	N/A	2	1	Operations and Training, Requirements/Specifications
38i	What are the impacts of reduced Gravity and atmospheric pressure on the food preparation activities?	3	2	1	Operations and Training, Requirements/Specifications
38j	What nutritional content and sensory attributes changes (including radiation induced effects) in the prepackaged food items will occur over the shelf life of the food?	2	2	2	Design Tools, Requirements/Specifications
38k	What food system technology selection criteria will be used to effectively reduce the use of critical resources such as air, water, thermal, biomass and solid waste processing, during a mission?	2	2	2	Design Tools, Requirements/Specifications
38l	What are the changes (taste, odor, etc.) that occur in crewmember's sensory perceptions during spaceflight that would affect food acceptability?	3	3	3	Requirements/Specifications
38m	What are the physical and chemical requirements for each of the crops and stored staple ingredient items to assure effective processing into acceptable, safe and nutritious food ingredients?	N/A	2	2	Requirements/Specifications
38n	What level of acceptable variety (e.g., number of food items, length of menu cycle) is required to provide psychosocial well-being of the crew?	3	3	2	Requirements/Specifications
38o	What modeling techniques can be used to measure the subjective portions of the food system such as palatability, nutrition, psychological issues and variety?	3	3	2	Design Tools, Requirements/Specifications

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***
Discipline:	***Advanced Life Support***
Risk:	***(39) Maintain Acceptable Atmosphere***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
39a	What new developments are needed to meet all the requirements for controlling trace contaminants, atmospheric pressure,	1	1	1	Requirements/Specifications, Technologies

	O2 and CO2 partial pressure?				
39b	What method for closing the O2 loop is most effective in an integrated ECLS?	2	2	2	Technologies
39c	What is the proper trace contaminant load and performance model to drive the design and operation of a trace contaminant system?	2	2	2	Design Tools
39d	Can viability and genetic integrity of the biological components be maintained for the duration of different missions?	4	3	2	Design Tools, Requirements/Specifications, Technologies
39e	What are the effects of radiation on biological components of the life support system?	3	3	1	Design Tools, Requirements/Specifications
39f	What research is required to validate design approaches for multiphase flow and particulate flows for air revitalization systems in varying gravity environments?	3	3	3	Requirements/Specifications, Technologies

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***				
Discipline:	***Advanced Life Support***				
Risk:	***(40) Maintain Thermal Balance in Habitable Areas***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
40a	What heat transport fluids meet the requirements for specified missions?	1	1	1	Design Tools, Technologies
40b	What materials and designs will meet the heat acquisition (cold plates, heat exchangers, cooling jackets, etc.) requirements for specified missions?	1	1	1	Design Tools, Technologies
40c	What materials and designs will meet the heat transport (pumps, two-phase loops, heat pumps, etc.) requirements for specified missions?	1	1	1	Design Tools, Technologies
40d	What materials and designs will meet the heat rejection (radiators, sublimators, evaporators, etc.) requirements for specified missions?	1	1	1	Design Tools, Technologies
40e	What materials and designs will meet the humidity control requirements for specified missions?	1	1	1	Design Tools, Technologies
40f	What thermal system sensors will meet the requirements to provide monitoring and data collection for specified missions?	2	2	2	Design Tools, Technologies
40g	What monitoring and control system hardware and design will meet the requirements for specified missions? (AEMC)	2	2	2	Design Tools, Technologies

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***

Discipline:	***Advanced Life Support***				
Risk:	***(41) Manage Waste***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
41a	What system will meet the storage and/or disposal requirements for specified missions?	1	1	1	Design Tools, Technologies
41b	What system will meet requirements for processing wastes to recover resources for specified missions?	1	1	1	Design Tools, Technologies
41c	What waste management will handle complex waste streams such as packaging, paper, etc. in order to meet mission requirements?	2	2	2	Design Tools, Technologies
41d	What waste management will handle medical wastes such as blood, tissues and syringes etc. in order to meet mission requirements?	2	2	2	Design Tools, Technologies
41e	What system will meet the requirements for managing residuals for planetary protection?	1	1	1	Technologies
41f	How can microbes and candidate crop species be engineered to perform better and fulfill multiple functions in a bioregenerative system?	4	3	1	Technologies
41g	What are the interfaces between the biological and physical chemical life support subsystems for a specified mission?	3	3	1	Design Tools, Requirements/Specifications
41h	Can viability and genetic integrity of the biological components be maintained for the duration of different missions?	4	3	2	Design Tools, Requirements/Specifications, Technologies
41i	How do partial and microgravity affect biological waste processing?	4	3	1	Design Tools, Requirements/Specifications
41j	What are the effects of radiation on biological components of the life support system?	3	3	1	Design Tools, Requirements/Specifications
41k	What sensors are required to monitor performance and provide inputs to control systems (AEMC)?	2	2	2	Design Tools, Technologies
41l	What monitoring and control system can provide semi to total autonomous control to relieve the crew of monitoring and control functions to the extent possible (AEMC)?	2	2	2	Design Tools, Technologies
41m	What studies need to be performed to determine whether or not recycling of solid waste can be done cost effectively to provide building materials for habitability features needed in subsequent phases of specified missions?	5	3	3	Research Requirements/Specifications
41n	What research is required to validate	3	3	3	Design Tools

	design approaches for multiphase flows for solid waste management and resource recovery in varying gravity environments.				
41o	What resources are required to manage waste disposal as an environmental risk during long and remote missions (from EH)?	4	3	1	Requirements/Specifications, Technologies
41p	What system will meet requirements for processing wastes to recover water for specified missions?	1	1	1	Technologies
41q	What system will meet requirements for processing wastes to recover CO2 for specified missions?	1	1	1	Technologies
41r	What system will meet requirements for processing wastes to recover minerals for specified missions?	1	1	1	Technologies
41s	How should wastes be handled or stored to avoid perception such as bad odors or unsightly appearance that would adversely affect crew quality of life and consequent degradation in performance?	2	2	2	Operations and Training, Technologies
41t	What waste management systems will prevent release of biological material (cells or organic chemicals that are signs of life) from contaminating a planetary surface, such as the Martian surface, and compromising the search for indigenous life?	N/A	4	1	Technologies
41u	What management systems will prevent release of biological materials that could harm indigenous biological communities?	3	2	1	Technologies
41v	What is the probability that waste materials could become reservoirs for return of indigenous life to Earth (i.e. backward contamination)? What systems can prevent this from occurring?	N/A	N/A	1	Technologies, Research Requirements/Specifications
41w	What is the probability that microorganisms in biological wastes such as food scraps or feces could be altered or mutated by the space environment radiation to become harmful or pathogenic? What can prevent this?	4	3	2	Research Requirements/Specifications
41x	What containment vessels will be sufficient to prevent escape of stored waste at various mission locations such as planetary surfaces or crew cabins?	4	3	1	Technologies

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***
Discipline:	***Advanced Life Support***
Risk:	***(42) Provide and Maintain Bioregenerative Life Support Systems***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**

42a	What are the optimal methods of plant growth for a specified mission, including development of appropriate hardware, management of light, water, nutrients, gas composition and pressure, trace contaminants, horticultural procedures and disease risks?	2	2	1	Design Tools, Technologies
42b	How can microbes and candidate crop species be engineered to perform better and fulfill multiple functions in a bioregenerative system?	4	3	1	Technologies
42c	What mechanized or automated systems are required for planting, harvesting, monitoring, and controlling crops for a specified mission?	4	3	2	Design Tools, Technologies
42d	Can viability and genetic integrity of the biological components be maintained for the duration of different missions?	4	3	2	Design Tools, Requirements/Specifications, Technologies
42e	What are the interfaces between the biological and physical chemical life support subsystems for a specified mission?	4	3	1	Design Tools, Requirements/Specifications
42f	How do partial and microgravity affect plant growth and crop yield?	4	3	1	Design Tools, Requirements/Specifications
42g	What are the effects of radiation on biological components of the life support system?	3	3	1	Design Tools, Requirements/Specifications
42h	What percentage of crew food needs should be attributed to ALS plant products for specified missions?	5	3	2	Design Tools, Requirements/Specifications
42i	What capabilities and associated hardware are required for processing and storing plant products for a specified mission?	5	3	2	Design Tools, Technologies
42j	Can the plant production rates and ALS functions be sustained for the duration of the mission?	5	3	1	Design Tools, Requirements/Specifications
42k	Can plant yields and ALS functions measured during low TRL (fundamental) testing be scaled up for large bioregenerative systems?	5	3	1	Technologies
42l	What sensors and monitoring systems will be required to measure environmental conditions and crop growth parameters and health for a specified mission (AEMC)?	3	3	2	Design Tools, Requirements/Specifications, Technologies
42m	What control system hardware and software technologies will be required to monitor and control crop systems for a specified mission (AEMC)?	3	3	2	Design Tools, Requirements/Specifications, Technologies

Crosscutting Area: Advanced Human Support Technologies (AHST)

Discipline:	***Advanced Life Support***				
Risk:	***(43) Provide and Recover Potable Water***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
43a	What system meets all requirements for supplying potable water needs?	1	1	1	Requirements/Specifications, Technologies
43b	What mechanisms to collect and transport wastewater meet the mission requirements?	1	1	1	Requirements/Specifications, Technologies
43c	What methods for the removal of organic, inorganic and microbial contaminants in wastewater meet all mission requirements for efficiency and reliability?	1	1	1	Requirements/Specifications, Technologies
43d	What method to store and maintain portability of recycled water meets all requirements for specified missions?	1	1	1	Requirements/Specifications, Technologies
43e	What sensors are required to provide water quality parameters, monitor performance and provide inputs to a control system (AEMC)?	2	2	2	Requirements/Specifications, Technologies
43f	What control system meets all mission requirements (AEMC)?	2	2	2	Requirements/Specifications, Technologies
43g	How can microbes be engineered to perform better and fulfill multiple functions in a bioregenerative system?	5	3	1	Technologies
43h	What are the interfaces between the biological and physical chemical life support subsystems for a specified mission?	5	3	1	Design Tools, Requirements/Specifications
43i	Can viability and genetic integrity of the biological components be maintained for the duration of different missions?	5	3	2	Design Tools, Requirements/Specifications, Technologies
43j	How do partial gravity and microgravity affect biological water processing?	N/A	3	1	Design Tools, Requirements/Specifications
43k	What are the effects of radiation on biological components of the life support system?	3	3	1	Design Tools, Requirements/Specifications
43l	What research is required to validate design approaches for multiphase flows for Water recovery systems in varying gravity environments?	1	1	2	Design Tools

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***				
Discipline:	***Space Human Factors Engineering***				
Risk:	***(44) Mismatch Between Crew Physical Capabilities and Task Demands***				
		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**

44a	What are the effects of microgravity, 1/6-gravity, or 1/3-gravity on requirements for habitable volume and architecture?	2	2	2	Design Tools, Requirements/Specifications
44b	What designs of workspace, equipment, tool and clothing will accommodate differences in crew anthropometry?	2	2	2	Design Tools, Requirements/Specifications
44c	What are the effects of duration of exposure to microgravity, 1/6-gravity, 1/3-gravity on human physical performance?	1	1	1	Design Tools, Operations and Training
44d	What tools, equipment and procedures will enable crew physical performance to accommodate the effects of exposure to different gravity levels?	2	2	2	Operations and Training, Requirements/Specifications
44e	How can crewmembers and ground support personnel detect and compensate for decreased physical readiness to perform during a mission?	2	3	3	Operations and Training, Technologies
44f	What scheduling constraints are required to reduce the risk of human performance failure due to physical fatigue to an acceptable probability?	2	2	2	Operations and Training, Requirements/Specifications
44g	What principles of task design and function allocation will result in operations concepts that meet crew performance requirements for the mission?	2	2	2	Design Tools, Requirements/Specifications
44h	What limitations are required on physical workload to enable crewmembers to complete physical tasks with an acceptable probability?	1	1	1	Design Tools, Requirements/Specifications
44i	What crew size, composition and task allocations are required to accomplish the reference missions?	1	1	1	Design Tools, Requirements/Specifications
44j	What design considerations are needed to accommodate effects of changes in gravity, including launch, reentry, lunar landing, lunar launch, Mars landing, Mars launch, and Earth return?	1	1	1	Design Tools, Requirements/Specifications

Crosscutting Area:	***Advanced Human Support Technologies (AHST)***
Discipline:	***Space Human Factors Engineering***
Risk:	***(45) Poorly Integrated Ground, Crew, and Automation Functions***

		R & TQ Priority			
No.	**R & T Questions**	**ISS**	**Lunar**	**Mars**	**R & T Category**
45a	What crew size and composition is required to accomplish the reference mission? (Shared - Integrated Testing supports)	2	1	1	Design Tools, Requirements/Specifications
45b	What principles and algorithms for allocating tasks to human crewmembers, ground support and onboard automated	1	1	1	Design Tools, Operations and Training

	systems will reduce the probability of significant errors? (Shared - Integrated Testing supports)				
45c	What automated tools and equipment are required to enable the crewmembers to accomplish the mission?	2	2	2	Requirements/Specifications, Technologies
45d	How do crew size, communications restrictions, crew skills, scheduling constraints and reference mission task requirements affect the requirements for automation?	1	1	1	Design Tools, Requirements/Specifications
45e	What combinations of crew, ground and on-board automation capabilities will increase the likelihood of a successful mission? (Shared - Integrated Testing supports)	1	1	1	Design Tools, Requirements/Specifications
45f	What training and operational readiness assurance processes and implementations will increase likelihood of mission success?	2	2	2	Design Tools, Operations and Training
45g	What principles of task assignment workload and automation need to be developed to facilitate critical team performance?	2	2	2	Operations and Training, Requirements/Specifications
45h	What tools and procedures are needed to determine the appropriate level of automation and crew control for the various tasks in the reference missions?	1	1	1	Operations and Training, Technologies